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AUTHORITY

USATEC ltr, 14 Dec 1970

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

RELIABILITY

1. OBJECTIVE

The objective of this Materiel Test Procedure is to describe the engineering test procedures for accumulating failure data on communication, surveillance, and avionic electronic equipment to serve as a basis, as prescribed by a selected test plan (Appendix A), for assessing the degree that the test item meets the reliability characteristics of the applicable Qualitative Materiel Requirement (QMR), Small Development Requirement (SDR), or Technical Characteristics (TC).

2. BACKGROUND

Reliability is defined in MIL-STD 721 as the probability that an item will perform its intended function for a specified interval under stated conditions. Because of its contribution to equipment availability and hence effectiveness, the reliability parameter is important in Army materiel.

Reliability is usually measured in terms of equipment Mean-Time-Between-Failures (MTBF) which can be translated to a probability of success (or failure) if the statistical distribution of failure times is known or can be determined.

The general reliability function or probability that an equipment will not fail during operation until time t is

$$R(t) = e^{-\int_0^t \lambda(t)dt} \tag{1}$$

where $\lambda(t)$ is the instantaneous failure rate at time t.

For a large class of electronic equipments, it has been observed that the failure rate characteristic for the equipment lifetime can be represented by the life cycle (bathtub) curve of Figure 1.

Period one (1) is the early failure or debugging period when high failure rate elements and workmanship defects are found. The failure rate is generally expected to decrease rapidly with time during this period.

Period two (2) is the constant failure rate period during which random failures occur and is the operational life span for which reliability is generally considered. Since the failure rate, $\lambda(t)$, is constant during this period, the reliability function or probability (of success or survival) that no equipment failures occur during the time interval 0 to t is

$$R(t) = e^{-\lambda t} \tag{2}$$

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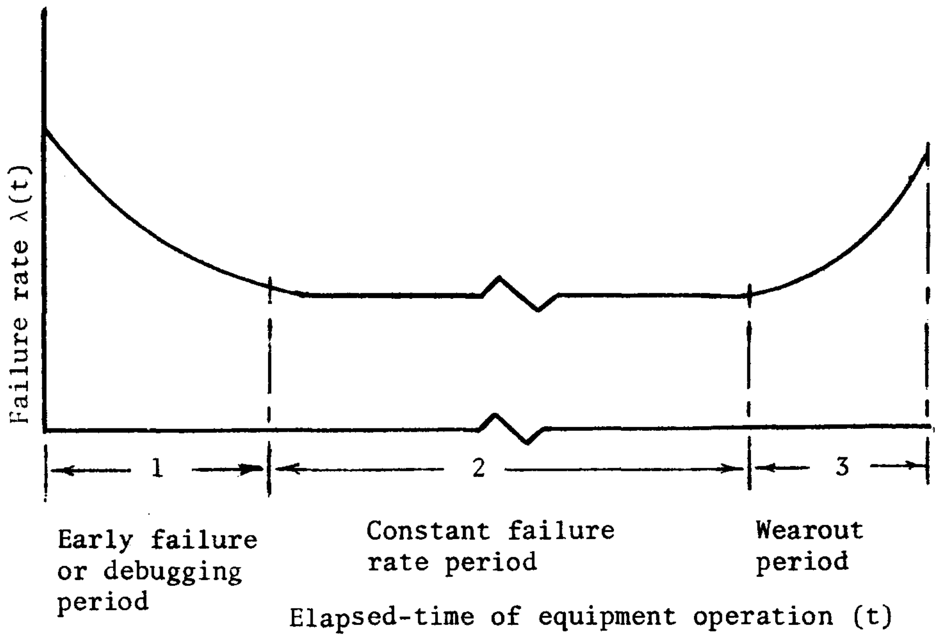

Figure 1. Life Cycle (bathtub) Curve for Electronic Equipment.

The exponential characteristic given by Equation 2 is also called the exponential law, and can be illustrated by the typical reliability curve for random failures as shown in Figure 2.

By differentiating the cumulative distribution function (1 - R(t)), which is the probability of failure until time t, the probability density function of Equation 3, of the exponential distribution, is obtained.

$$f(t) = \lambda e^{-\lambda t} \tag{3}$$

The expected time to failure or Mean-Time-Between-Failures (MTBF) is then given by

$$\text{MTBF} = E(T) = \int_0^\infty t\lambda e^{-\lambda t} dt = \frac{1}{\lambda} \tag{4}$$

Period three (3) of the life cycle curve is the wearout period when some elements of the equipment fail from wear. Usually, if such a period is known to exist within the useful life of the equipment, the equipment may be scheduled for overhaul before it fails from wear.

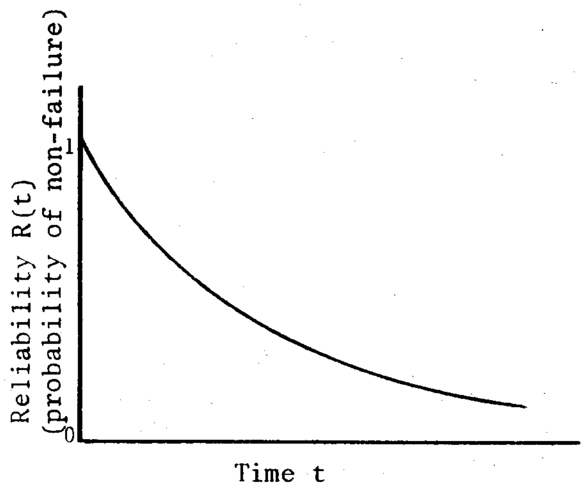

Figure 2. Typical Reliability Curve for Random Failures.

This "wearing out" occurs continuously throughout the life cycle of electronic equipment; i. e., batteries, tubes, certain transistors and so on. Any item having a stipulated life which is substantially shorter than the life of the equipment should be considered "worn out" at the time it accomplishes its stipulated life. If it fails before its stipulated life, it should be counted as a relevant failure. If it is replaced before its stipulated life without its failing, the replacement should not be counted as a relevant failure. If it fails after its stipulated life, it should be regarded as a non-relevant failure.

To ensure the achievement of reliability in developmental equipment and the suitability of the equipment for service test, engineering reliability tests must be performed.

3. REQUIRED EQUIPMENT

a. Test facilities, as required by applicable test level, (Appendix C).
b. Elapsed operating time meter.
c. Thermocouple with associated instrumentation..
d. Test apparatus, as required for operational tests.
e. Support equipment, as required to operate test item.

4. REFERENCES

A. MIL-STD-785( ), Reliability Program for Systems and Equipment: Development and Production.

B. MIL-STD-781 ( ), Reliability Tests: Exponential Distribution.
C. MIL-STD-721 ( ), Definitions of Effectiveness Terms for Reliability, Maintainability, Human Factors and Safety.
D. MIL-STD 757 ( ), Reliability Evaluation from Demonstration Data.
E. MIL-R-22973(WEP), Reliability Index Determination for Avionic Equipment Models, General Specification for.
F. AR 70-10, Test and Evaluation during Research and Development of Material.
G. AR 750-6, Maintenance Support Planning.
H. AR 705-50, Army Materiel Reliability and Maintainability
I. AMC Pamphlet 702-3, Quality Assurance: Reliability Handbook.
J. NASA CR-1128, Practical Reliability - Volume III - Testing prepared by Research Triangle Institute, Research Triangle Park, N. C., for NASA, August 1968 (CFSTI N68-32779).
K. Ireson, W. G. (ed), Reliability Handbook, McGraw-Hill, New York 1966.
L. NAVWEPS 00-65-502, Handbook: Reliability Engineering, Bureau of Naval Weapons, Washington, D. C., 1 June 1964.
M. Von Alven, W.H., (ed), Reliability Engineering, Prentice-Hall, Englewood Cliffs, New Jersey, 1964.
N. MIL-STD-810B, Environmental Test Methods.
O. Terms and Definitions for Testing Reliability, Maintenance, and Availability Characteristics of Electronic Systems U. S. Army Electronic Proving Ground, Fort Huachuca, Arizona September 1969.
P. USATECOM Regulation 385-6, Verification of Safety of Materiel During Testing.
Q. AMCR 385-12, Verification of Safety of Materiel from Development through Testing, Production, and Supply to Disposition.
R. MTP 3-1-002, Confidence Intervals and Sample Size.
S. MTP 6-2-507, Safety.

5. SCOPE

5.1 SUMMARY

The procedures outlined in this MTP describe in general terms the engineering tests required to evaluate the reliability characteristics of Communication, Surveillance, and Avionic electronic equipment.

The cumulative test results will permit an estimate to be made of the degree of compliance of the item under test with applicable specifications and requirements, and the suitability of the item for service test.

The specific tests to be performed provide for exposing the operational test item(s) to defined or controlled stress conditions at a specific test level (See Appendix C) commensurate with the environmental operating requirements of the equipment in order to obtain failure data.

5.2 LIMITATIONS

The procedures given in this document are limited to the engineering testing of electronic equipment under defined or controlled stress conditions (test levels) to obtain failure for the test item to the extent stipulated in selected or prepared reliability test plans (Appendix A). Determination of sample size and of confidence levels or risks associated with reliability estimation or demonstration, are not included herein.

No assumption is made herein that the underlying distribution of failure times for the test item is exponential, although this assumption is included in the test plans of Appendix A. In the absence of any verification data from prior testing of the test item, it is recommended that the verification procedure for the exponential assumption such as in Appendix B be included in any reliability test plan.

6. PROCEDURES

6.1 PREPARATION FOR TEST

a. Upon establishing the scheduled availability of the test item coordinate the availability of the following:

1) Engineering safety release or other safety statement.
2) Maintenance support facilities, spare parts, and personnel.
3) Equipment, special facilities, and instrumentation with special attention to timely provision of additional supplies or special equipment not readily available at the test site.

b. Select a testing facility using the following criteria:

1) The volume of the test facility must be such that the equipment under test can be either operating or not operating and, will not interfere with the generation and maintenance of test environmental conditions.
2) All apparatus used in conducting these tests must be capable of producing and maintaining the test conditions required.

c. Select test equipment ideally having an accuracy of at least ten orders of magnitude greater than that afforded by the item under test, that is in keeping with the state of the art, and with calibrations traceable to the National Bureau of Standards.

d. Record the following information:

1) Nomenclature, serial number(s), manufacturer's name, and function of the item(s) under test.
2) Nomenclature, serial number, accuracy tolerances, calibration requirements, and last date calibrated of the test equipment selected for the test.

e. Ensure that all test personnel are familiar with the required

technical and operational characteristics of the item under test, such as stipulated in Qualitative Materiel Requirements (QMR), Small Development Requirements (SDR), and Technical Characteristics (TC).

f. Review all instructional material issued with the test item by the manufacturer, contractor, or government, as well as reports of previous similar tests conducted on the same types of equipment. These documents shall be kept readily available for reference.

g. Prepare record forms for systematic entry of data including the pretest equipment record, chronology of test, test results, and such observations and measurements that would be of value in analysis and final evaluation.

h. Prepare adequate safety precautions to provide safety for personnel and equipment, and ensure that all safety SOP's are observed throughout the test and that the item has successfully completed the examination prescribed in MTP 6-2-507, Safety.

i. Prepare a test item sample plan sufficient to ensure that enough samples of all measurements are taken to provide statistical confidence of final data in accordance with MTP 3-1-002. Provisions shall be made for modification during test progress as may be indicated by monitored test results.

j. Thoroughly inspect the item under test for obvious physical and electrical defects such as cracked or broken parts, loose connections, bare or broken wires, loose assemblies, bent relay and switch springs, corroded plugs and jacks, and bare or cracked insulation. All defects shall be noted and corrected before proceeding with the test.

k. Prepare the test facility for testing by performing a functional checkout procedure to include adjustment or servicing as required, and performance of appropriate maintenance (see Appendix C).

6.2 TEST CONDUCT

NOTE: This test shall be performed until sufficient failure and operating-time data for the test item has been accumulated to meet the requirements of the specific test plan, that is, to permit a reliability estimate or decision to be made relevant to the particular test plan criteria.

a. Install the test item(s) in the test facility in accordance with the guidance given in Appendix C, and in a manner that will simulate service usage.

NOTE:
1. Allow plugs, covers, and inspection plates not used in operation, but used in servicing, to remain in place.
2. When mechanical or electrical connections are not used, adequately cover the connections normally protected in service.

b. Install instrumentation as necessary to meet the requirements of the test and to provide for the safety of the equipment, the test facility, and the test personnel.

c. Provide suitable arrangements to start, operate, monitor, and stop the item under test without materially affecting the environment or the

validity of the test.

d. Verify correct power source, interconnection cabling, and that the unit is aligned, if necessary, as specified in the pertinent operating instructions to ensure, insofar as possible, it represents an average equipment in normal operating condition and that no damage or malfunction was caused by faulty installation or handling.

e. Operate the test item under standard ambient conditions, unless otherwise specified, and record all data necessary to determine compliance with required performance.

NOTE: These data shall provide the criteria for checking satisfactory performance during or at the conclusion of the test.

f. Conduct a thermal survey on the test item, under the temperature cycling and duty cycle of the applicable test level, for the identification of the component of greatest thermal inertia and the establishment of the time-temperature relationships between it and the environmental air. Temperatures of the heating-cooling air shall be recorded continuously during both survey and testing.

NOTE: 1. The time-temperature relationships shall be used for determining equipment thermal stabilization during the test.

2. Temperature stabilization is considered to be achieved when the temperature of that part of the test item with the largest mass does not change more than 2.0° C (3.6° F) per hour.

g. Conduct a vibration survey, as practicable, to search for resonant conditions between 20 and 60 H_z in order that they may be avoided during the reliability test.

h. With the equipment off, apply the lower test level temperature to the equipment and when the equipment temperature has stabilized, begin the test. When no temperature cycling is required by the test level, the test shall begin when the equipment temperature stabilizes at the specified test level temperature.

NOTE: Temperature stabilization is considered to be achieved when the temperature of the part of the test item with the largest mass does not change more than 2.0° C (3.6°F) per hour.

i. Turn the equipment on and operate it in accordance with the specified duty cycle. Simultaneously, apply the higher test level temperature to the equipment until the equipment temperature has stabilized, and there-after for the specified period of time. If no such time is specified, the period shall be two (2) hours. Apply the test level vibration and other environmental stresses during this heating cycle.

j. During the high temperature stabilization, measure and record each required equipment performance parameter at least daily, unless otherwise specified. If the value of any specified equipment parameter is not within

tolerance, record a failure and take required action.

NOTE: Assume any failure to have occurred immediately after the last successful measurement of the same parameter unless it is known when the failures occurred.

k. On the occasion of a failure (any operation outside specified limits), make entries on the appropriate data logs and remove the failed equipment from test with minimum interruption of test of equipments which continue to meet test performance requirements.

l. Repair the failed equipment. All failed parts shall be replaced; any part which has deteriorated but does not exceed specified tolerance limits shall not be replaced.

m. After repair to operable condition, return the equipment to test without interruption to the equipments continuing on test, and make appropriate entries into the data logs.

NOTE: The absence of one or more equipments for the purpose of repair shall not affect the ability to make decisions from log data.

n. Unless otherwise specified, at the end of the heating cycle, turn the equipment off and apply the lower test level temperature to the equipment until the equipment temperature has stabilized. When the alternative temperature cycle of Figure C-2 is specified at the end of the high temperature test, continue operating the equipment, apply the lower test level temperature to the equipment until the equipment temperature has stabilized, and operate the equipment for the specified time. If no such time is specified, the period shall be two (2) hours.

o. The testing sequence is heating, measuring, and cooling. This sequence shall be repeated until a failure occurs or the total required test time is completed. When failures occur and the equipment is repaired, testing shall resume, preferably in that part of the sequence where the failures occurred.

6.3 TEST DATA

6.3.1 Preparation for Test

Data to be recorded prior to testing shall include but not be limited to:

a. Nomenclature, serial number(s), manufacturer's name, and function of the item(s) under test.

b. Nomenclature, serial number, accuracy tolerance, calibration requirements, and last date calibrated of the test equipment selected for the tests.

6.3.2 Test Conduct

Data to be recorded during test conduct shall include:

a. A block diagram of the test setup employed in each test. The block diagram shall identify by model and serial number, all test equipment and interconnections (cable lengths, connectors, attenuators, etc.) and indicate control and dial settings where necessary.

b. Photographs or motion pictures (black and white or color), sketches, charts, graphs, or other pictorial or graphic presentation which will support test results or conclusions.

c. An engineering logbook containing, in chronological order, pertinent remarks and observations which would aid in a subsequent analysis of the test data. This information may consist of temperatures, humidity, pressures, and other appropriate environmental data, or other description of equipment or components, and functions and deficiencies, as well as theoretical estimations, mathematical calculations, test conditions, test parameters, etc., that were obtained during the test.

d. Test item sample size (number of measurement repetitions).

e. Instrumentation or measurement system mean error stated accuracy .

f. Initial operational data for the test item and test facility indicating proper operation under the test conditions, as applicable.

g. Identity of the component of greatest thermal inertia (temperature stabilization point).

h. Temperature versus time of the temperature stabilization point.

i. Temperature versus time of the environment air.

j. Resonant frequencies of the test item, as applicable.

k. The following each time a check is made on the equipment under test:

1) Date.
2) Time.
3) Time meter reading.
4) Values of measured environmental, input, and performance parameters.
5) Pertinent notes.

NOTE: Figure 3 may be used as a guide for the test log sheet.

l. The following for each failure action:

1) Failure report number.
2) Time, data, and time meter reading, upon removal of test item for repair.
3) Time, date, and time meter reading, upon return of test item to test.
4) Description of failure.

NOTE: Figure 4 may be used as a guide for the equipment failure record.

m. The following for relevant failures of all equipments under test:

1) Failure report number.
2) Unit serial number
3) Unit time meter reading.
4) Description of failure.
5) Test status of all units, including cumulative failures, cumulative test hours, and MTBF.

NOTE: Figure 5 may be used as a guide for the failure summary record.

6.4 DATA REDUCTION AND PRESENTATION

Present the following:

a. Description of the reliability test plan.

b. Estimated achieved MTBF of the test item, with a confidence level and range, as applicable.

c. Graph of the accept/reject criteria with failure-time data plotted thereon to the decision point, and a decision statement, as applicable.

d. Longevity characteristic of the test item, as applicable.

e. Description and analysis of failures.

f. Correlation of the obtained data with reliability data from other tests on the test item with a conclusion relevant to degree of reliability increase.

g. Overall assessment of the reliability characteristic of the test item.

TEST LOG AND DATA RECORD

TEST TYPE____________________

EQUIPMENT TYPE________________ SERIAL NO.______________ DATE TEST INITIATED__________________

LINE NO.	DATE	TIME	TIME METER READING	PARAMETERS			ENTRY	TECH INITIALS
				ENVIRONMENTAL	INPUT	PERFORMANCE		
				TITLE COLUMNS AS APPROPRIATE	TITLE COLUMNS AS APPROPRIATE	TITLE COLUMNS AS APPROPRIATE		

FIGURE 3 Sample Test Log and Data Record

TYPE TEST______________ TEST POSITION______________

EQUIPMENT TYPE__________ DATE TEST INITIATED_________

UNIT SERIAL NO.__________

LINE NO.	FAILURE REPORT NO.	REMOVAL FOR REPAIR		RETURN TO TEST		DESCRIPTION OF FAILURE	TECH INITIALS
		TIME/ DATE	TIME METER READING	TIME/ DATE	TIME METER READING		

Figure 4 Sample Equipment Failure Record.

FAILURE SUMMARY RECORD

TEST TYPE ____________________

EQUIPMENT TYPE ________________ DATE TEST INITIATED ____________

DATE	FAILURE REPORT NO.	UNIT SERIAL NO.	UNIT TIME METER READING	DESCRIPTION OF FAILURE	TEST STATUS - ALL UNITS CUMULATIVE FAILURES	TEST STATUS - ALL UNITS CUMULATIVE TEST HOURS	TEST STATUS - ALL UNITS MTBF	TECH INITIALS

Figure 5 Sample Failure Summary Record

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GLOSSARY

Decision Risks: Consumer's Decision Risk (β) - The probability of accepting equipment(s) with a true MTBF equal to the minimum acceptable MTBF (Θ_1). Producer's Decision Risk (α) - The probability of rejecting equipment(s) with a true MTBF equal to the specified (Θ_0).

Discrimination Ratio (Θ_0/Θ_1): The ratio of the specified MTBF (Θ_0) to the minimum acceptable MTBF (Θ_1).

Failure: Equipment Failure - The inability of a previously acceptable item to perform its required function within previously established limits.

Pattern Failure - The occurrence of two or more failures of the same part in identical or equivalent application whose combined failure exceeds that predicted.

Relevant Failure - All failures are relevant unless caused by a condition external to the equipment under test which is not a test requirement and not encountered in service. Certain parts of known limited life, such as batteries, may have a life stipulated prior to initiation of testing. Failures of these parts occurring prior to the end of the stipulated period are relevant. Failures chargeable to workmanship deficiencies in the equipment are relevant.

Independent Failure - A failure which will independently cause equipment performance outside of specified limits - one which occurs without being related to the failure of associated items.

Dependent Failure - A failure of a part which is a direct result of an independent failure - one which is caused by the failure of an associated item(s).

Longevity: The specified period of time during which it is economically feasible to repair the equipment and return it to the original operating condition. Longevity is synonymous with useful operating life.

Mean Time Between Failures (MTBF): Observed MTBF (Θ) is equal to the total operating time of the equipment divided by the number of failures. The MTBF is also the reciprocal of the constant failure rate.

Minimum Acceptable MTBF (Θ_1) - A value so selected that an associated and specified risk of accepting equipment of this value is tolerable.

Specified MTBF (Θ_0) - The MTBF value specified in the equipment specification or other requirements document.

Failure Rate: The number of failures of an item per unit measure of life (cycles, time, miles, events, etc., as applicable for the item).

Availability: A measure of the degree to which an item is in the operable and committable state at the start of the mission, when the mission is called for at an unknown (random) point in time.

Burn-In (or Debugging) Period: Period of equipment operation for a certain time prior to the initiation of reliability testing. Any such burn-in applied to test samples is applied to all items of equipment submitted for acceptance. Failures occurring during this period may be considered non-relevant but are recorded and reported. Burn-in for all items of equipment submitted for acceptance is conducted at the same level of environment and for the same integral number of cycles as the burn-in conducted on test samples.

APPENDIX A

RELIABILITY TEST PLANS

In general, reliability test plans provide for the selection of a sample of equipments, the placement of the sample on test in accordance with some specific test level, and the accumulation of sufficient failure and operating-time data to permit a reliability estimate or decision to be made relevant to the particular test plan criteria. The test level is normally selected to simulate as closely as practicable the actual use (environmental and stress) conditions of the test item to ensure that the resulting data will be of significant value.

Typical military reliability measurement and demonstration test plans include the following:

a. Reliability Index Determination (MIL-R-22973).
b. Reliability Qualification (Demonstration), as follows:

    1) Standard Probability Ratio Sequential Tests (PRST) (MIL-STD-781, Test Plans I through VI).
    2) Short Run High Risk PRST Plans (MIL-STD-781, Test Plans VII through IX).
    3) Fixed Length Test Plans (MIL-STD-781, Test Plans X through XXVII).

c. Longevity Test Plan (MIL-STD-781, Test Plan XXVIII).

The reliability index determination test plan provides for the measurement of equipment reliability in terms of Mean-Time-Between-Failures (MTBF) with an associated confidence level and MTBF range, for a specific test level.

The reliability qualification (demonstration) test plans provide for the determination of the acceptability of the reliability characteristic of the equipment submitted to test, based upon the assumption of decision risks, for a specific test level.

Standard PRST plans are used when a sequential test plan with normal (10 to 20%) producer and consumer risks are desired.

Short-run high risk PRST plans may be used when a sequential test plan is desired, but circumstances require the use of a short test with a low discrimination ratio and both the producer and consumer are willing to accept relatively high decision risks.

Fixed length test plans may be used when the exact length and costs of tests must be known beforehand. However, PRST plans with similar risks and discrimination ratio will be more efficient and economical than

the fixed length test plans.

The longevity test plan provides for the determination of the capability of the equipment to meet performance requirements over a specified extended period of time.

Reliability test plans may also include tests under field-use conditions such as in a desert environment with the test level defined.

APPENDIX B

VERIFICATION OF VALIDITY OF THE EXPONENTIAL ASSUMPTION FOR FAILURE TIMES

The exponential function is generally valid for the useful operating life of electronic systems, equipments, and components. However, if actual failure rate data do not support the exponential assumption, that is, if early failure or wearout periods are significantly involved for the test item during reliability testing, then the assumption is not valid and any inferences (estimates or decisions) based upon the test plans of Appendix A may be incorrect.

A graphical procedure is useful for a quick indication of the validity of the exponential assumption provided that the number of observed failures is relatively large. The procedure is to plot the cumulative test or operating time against the cumulative number of failures r, as shown in Figure B-1, indicating a straight line plot.

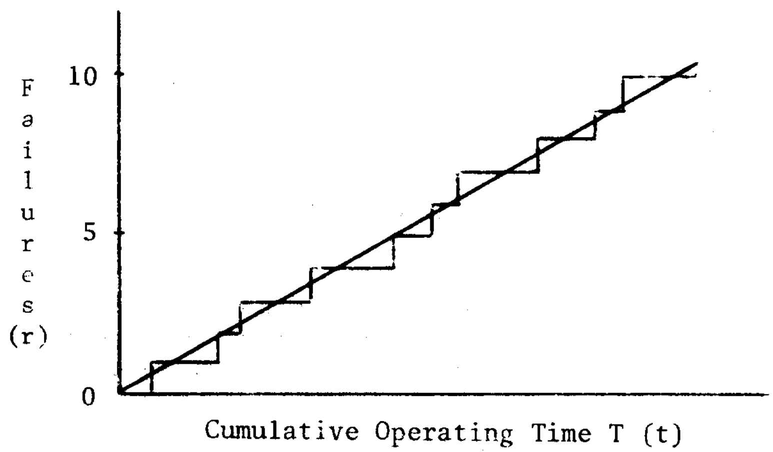


Figure B-1. Plot of Time versus Failures

A further refinement on the graphical procedure is shown in Figure B-2. Here cumulative time at each failure is plotted against the quantity

$$Y_i = L_n \left(\frac{n+1}{n-i+1}\right)$$

where n is the number of original test items plus replacements in a replacement test, i is the number of failures, and times are recorded as time between failure.

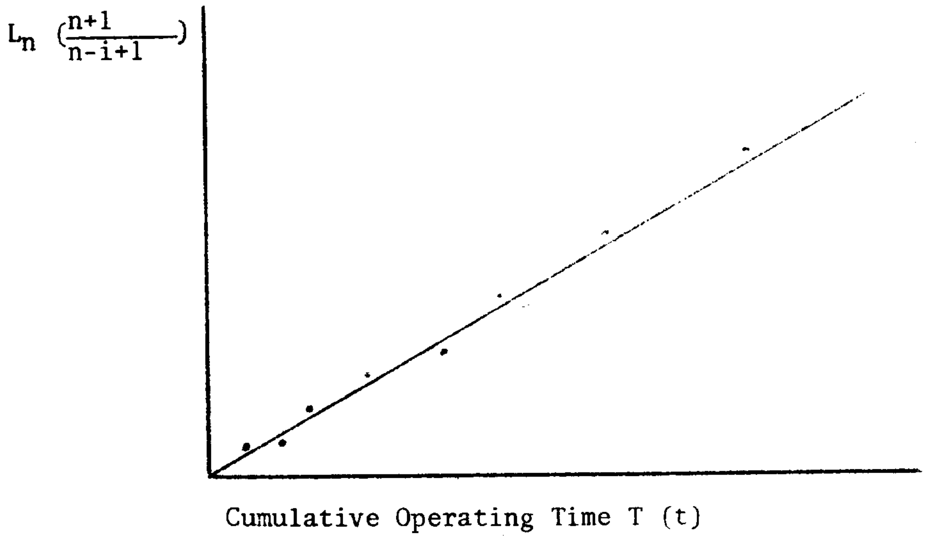


Figure B-2. Plot of Time versus $L_n \left(\frac{n+1}{n-i+1}\right)$

If necessary, statistical "goodness of fit" (Kolmogorov-Smirnov or d-test, and chi-square) tests may be used to determine whether the assumption of exponential distribution of failure times is reasonable.

APPENDIX C

RELIABILITY TEST LEVELS

1. GENERAL

The test levels given in this Appendix describe the conditions of temperature, vibration, input voltage, and the cycling of these conditions to be applied to the equipment during the reliability test, and are summarized in Table C-I.

The requirements outlined in Table C-I are considered minimal. The test officer may modify the individual test levels to meet more stringent conditions. However, under the majority of conditions, the assignment of test stress levels is based on the considerations that the test level shall:

a. Be severe enough to equal or exceed the anticipated operational stress.

b. At least equal the operating temperature extremes of the class of the general electronic specification which is referenced, such as MIL-E-5400, and approach or equal the design maximum and minimum.

c. Be severe enough to uncover defective parts or workmanship.

d. Not exceed basic design parameters to such an extent that nonrelevant failure modes become significant.

2. TEMPERATURE CYCLING

The method and duration of temperature cycling may be specified in the equipment specification or other requirements document. If no method of temperature cycling is specified, the standard cycling method of the following paragraph a., shall be used. When specified, the alternative method of cycling in paragraph b., shall be used.

NOTE: When no temperature cycling is required, the equipment duty cycle (paragraph C5) shall be continuously repeated for the duration of the test.

a. Standard Method of Temperature Cycling - Stabilize the equipment temperature at the lower test level temperature. Turn the equipment on and allow it to experience the combined effect of chamber heating and equipment operation until the point of maximum thermal inertia stabilizes at the higher temperature as determined in accordance with the thermal survey. Maintain the equipment at the upper test level temperature for a period of time as specified. If no such time is specified, the period shall be two hours. Turn the equipment off and allow it to experience chamber cooling until stabilization is achieved at the lower test level temperature. This cycle shall continue for the duration of the test. Figure C-1 portrays the temperature-time profile for temperature cycling.

NOTE: Temperature stabilization is considered to be achieved

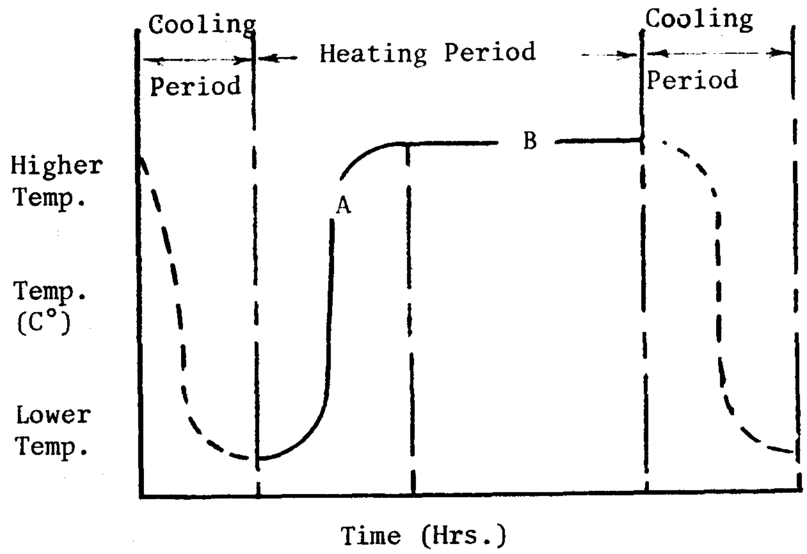
when the temperature of that part of the test item with the largest mass does not change more than 2.0°C (3.6°F) per hour.

b. Alternative Method of Temperature Cycling - This temperature cycle allows the equipment to operate at upper and lower extremes after stabilization for specified time periods. If no time periods are specified, each period shall be two hours. The cycle shall continue for the duration of the test. Figure C-2 portrays the temperature-time profile for this method of temperature cycling.

TABLE C-I. SUMMARY OF TEST LEVELS

TEST LEVEL	TEMPERATURE °C	TEMPERATURE CYCLING (Par C2)	VIBRATION (Par C3)	EQUIPMENT ON/OFF CYCLE (Par C4)
A	25 ± 5 (68 to 86°F)	NONE	YES	YES
A-1	25 ± 5 (68 to 86°F)	NONE	NONE	NONE
B	40 ± (95 to 113°F)	NONE	YES	YES
C	50 ± 5 - 0 (122 to 131°F)	NONE	YES	YES
D	65 ± 5 (140 to 158°F)	NONE	YES	YES
E	-54 to +55 (-65 to 131°F)	YES	YES	YES
F	-54 to +71 (-65 to 160°F)	YES	YES	YES
G	-54 to +95 (-65 to 203°F)	YES	YES	YES
H	-65 to +71 (-85 to 160°F)	YES	YES	YES
J	-54 to +125 (-65 to 257°F)	YES	YES	YES

Input voltage shall be the nominal specified voltage +5 -2%.
Input voltage cycling (paragraph C6) may be applied to any of the Test Plans (Appendix A).

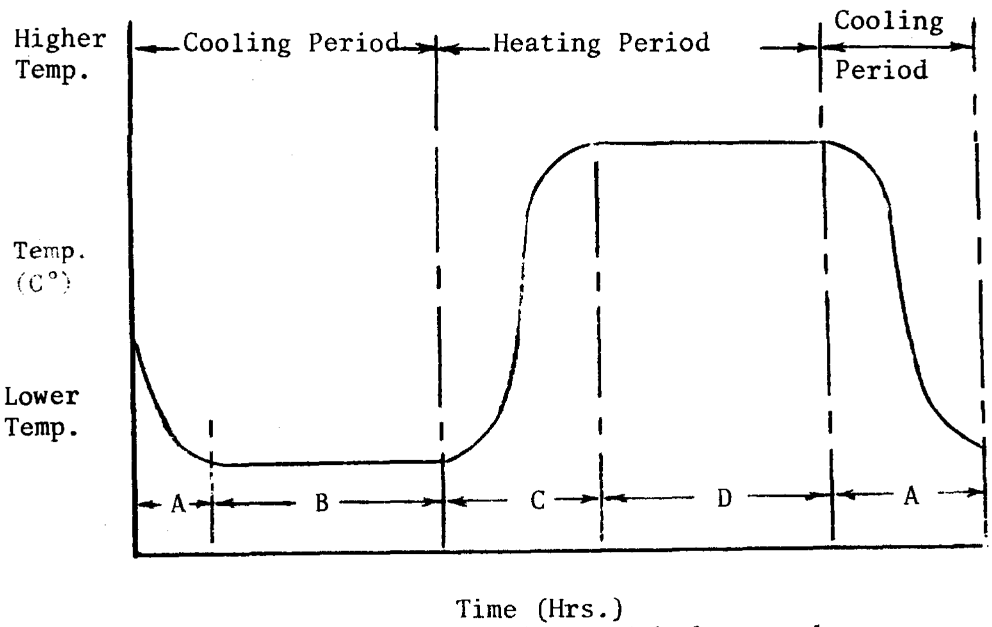


----Equipment off ——Equipment operated in accordance with duty cycle

A - Time for equipment to stabilize at higher temperature

B - Time of stabilized equipment operation at higher temperatures

Figure C-1. Temperature-Time Profile for Standard Temperature Cycling.



Equipment operated in accordance with duty cycle

A - Time for equipment to stabilize at lower temperature

B - Time for stabilized equipment operation at lower temperature

C - Time for equipment to stabilize at higher temperature

D - Time for stabilized equipment operation at higher temperature

Figure C-2. Temperature-Time Profile for Alternative Temperature Cycling

3. VIBRATION

The vibration shall be 2.2G ± 10% peak acceleration value at any nonresonant frequency between 20 and 60 H_z measured at the mounting points on the equipment. If the equipment is designed to meet a vibration requirement less severe than specified herein, the vibration may be reduced to the level specified as a design requirement. The duration of vibration shall be at least 10 minutes during each hour of equipment operating time. When the equipment to be tested contains circuit boards or cards, vibration shall be normal to the plane of the majority of the cards. Otherwise, the direction of vibration is not critical.

NOTE: 1. This vibration requirement may be met by mounting the equipment solidly, that is, without the equipment shock vibration mounts, to a durable flat plate which is supported by vibration isolators. The desired amplitude and frequency may be obtained by a simple vibration machine with an asymmetric weight on a shaft attached to the plate and driven by a suitable motor.
2. It is recommended that the vibration equipment be checked for proper operation each 24 hours of operation, and that the vibration transducer be "on" and monitored continuously during vibration.

4. EQUIPMENT ON-OFF CYCLING

Unless otherwise specified, such as in paragraph C2b, the equipment shall be "on" during the heating cycle and "off" during the cooling cycle. For those test levels which do not require equipment on-off cycling, such as Test Levels A, B, C, and D, the equipment shall be turned on and allowed to temperature-stabilize, held for 3 hours, then turned off and allowed to temperature-stabilize. This cycle shall continue throughout the test.

5. DUTY CYCLE

The duty cycle (or performance profile) is the time phase apportionment of modes of operation and functions to be performed by the equipment during the on-time portion of the environmental test cycle. It is intended that the duty cycle be representative of field operation. The equipment specification or other requirements document will specify the duty cycle to be used during the tests.

NOTE: If no equipment on-off cycling is required by the test level, the specified duty cycle is to be used during the tests.

6. VOLTAGE CYCLING

When no tolerance limits are specified in the equipment specification or other requirements document for the input voltage, but a nominal

value is furnished, voltage cycling shall be accomplished as follows: The input voltage shall be maintained at 110 percent nominal for one-third of the equipment "on" cycle, at the nominal value for the second one-third of the equipment "on" cycle, and at 90 percent for the final one-third of the equipment "on" cycle. This cycling procedure is to be repeated continuously throughout the test.

When tolerance limits are specified with the nominal value of the input voltage, the following cycling procedure of input voltage is to be repeated continuously throughout the test: the input voltage shall be maintained at the upper tolerance value specified for one-third of the equipment "on" cycle, at the nominal value for the second one-third and at the lower tolerance value specified during the final one-third of the cycle.

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13. ABSTRACT
This Engineering Test Procedure describes test methods and techniques for evaluating the Reliability Characteristics of Communications, Surveillance, and Avionic Electronic Equipment. The procedures are intended to be limited to the engineering testing of electronic equipment under certain selected reliability test plans. The evaluation is related to criteria expressed in applicable Qualitative Material Requirements (QMR), Small Development Requirements (SDR), Technical Characteristics (TC), or other appropriate design requirements and specifications for the specific test items.

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